

Research on Net Zero at the Health and Safety Executive (HSE)

Simon Gant, Strategic Science Adviser for Net Zero, HSE

31st International Conference on Modelling,
Monitoring and Management of Air Pollution

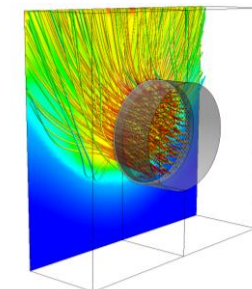


Outline

- Introduction to HSE
- Hydrogen
- Carbon Capture Utilisation and Storage (CCUS)
- Ammonia
- Batteries
- Future directions

Introduction to HSE

- HSE is the regulator for workplace health and safety in Great Britain
 - Includes onshore/offshore pipelines, chemical/oil/gas infrastructure, offshore platforms etc.
 - Activities: evidence gathering, policy development, consultation, regulation, incident investigation, enforcement
 - 3,000 total staff (FTE): £310M annual budget, 66% from Government*
-
- HSE Science and Research Centre, Buxton, UK
 - 400 staff, 550-acre test site
 - Scientific support to HSE and other Government departments
 - “Shared research” or joint-industry projects co-funded by HSE
 - Bespoke consultancy on a commercial basis

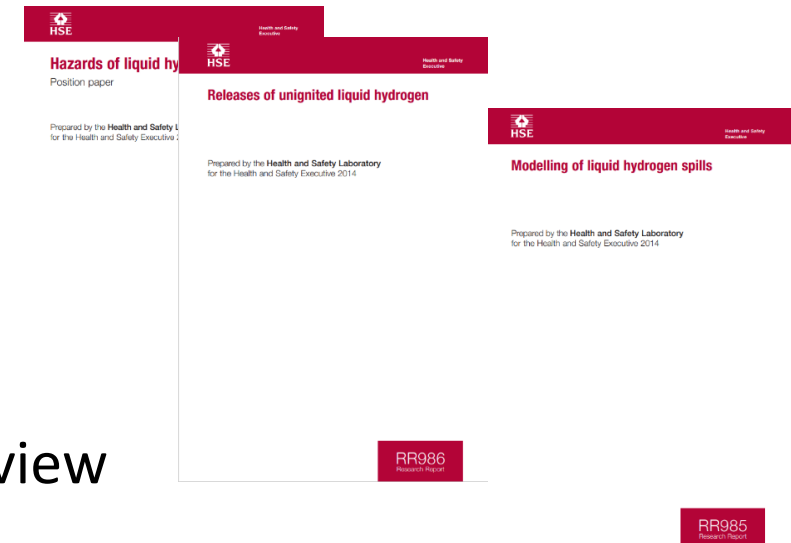


* <https://www.gov.uk/government/publications/the-health-and-safety-executive-annual-report-and-accounts-2024-to-2025>

Hydrogen

Examples of HSE publications on hydrogen

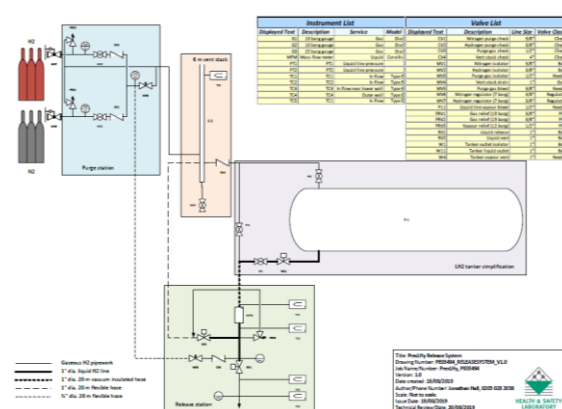
- RR1169 – Hydrogen in the natural gas distribution network: Preliminary analysis of gas release and dispersion behaviour
- RR985 – Modelling of liquid hydrogen spills
- RR986 – Releases of unignited liquid hydrogen
- RR987 – Ignited releases of liquid hydrogen
- RR1159 – Hydrogen research priorities workshop
- RR615 – Spontaneous ignition of hydrogen: Literature review

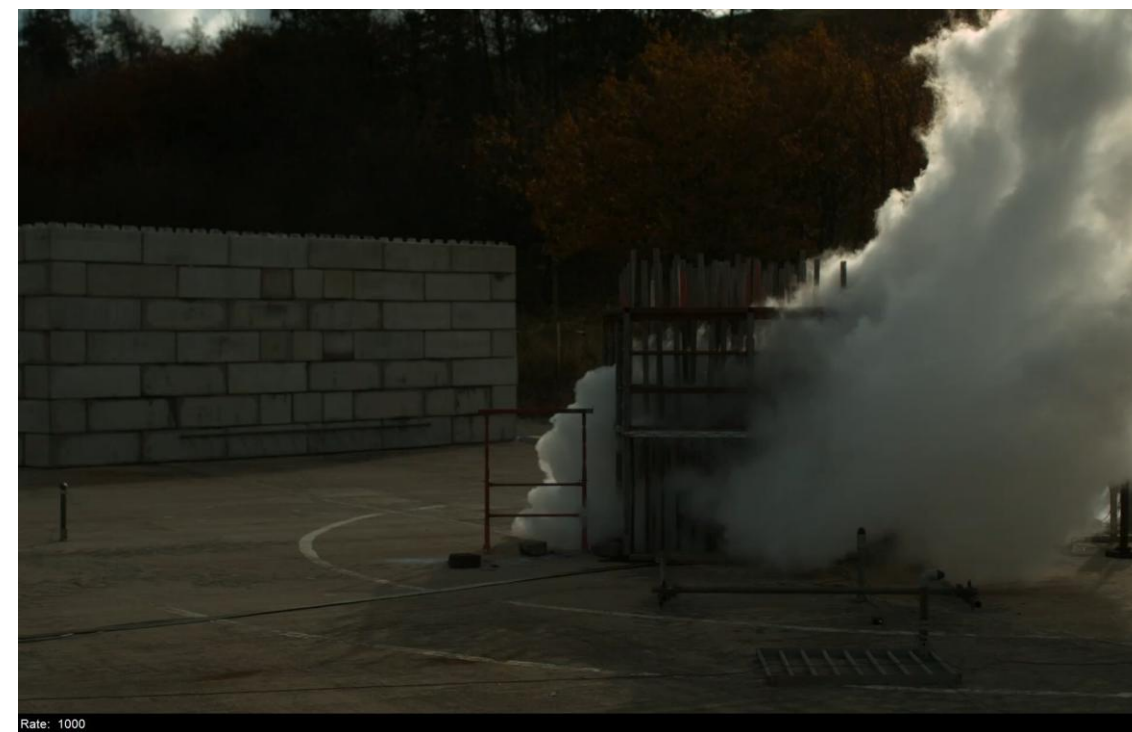


<https://www.hse.gov.uk/research/rrhtm/index.htm>

PRESLHY

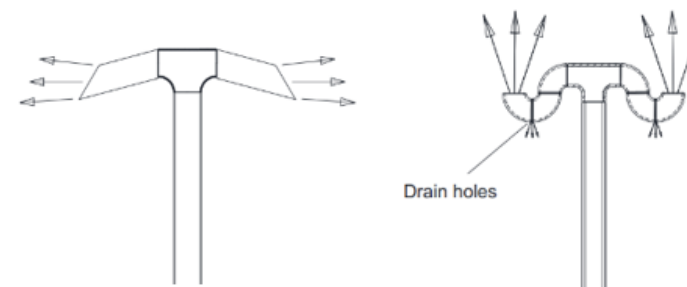
- Pre-normative research on the safe use of liquid (cryogenic) hydrogen as an energy carrier
- 3-year test programme, 2018 – 2020
- Experiments on source term characterisation, near- and far-field dispersion, fire-fighting measures, explosion overpressures, electrostatic charging and condensed phase assessment
- Flows ranged from 1-5 barg at source with flow rates up to 300 g/s in 1" pipework
- EU FCH JU 2.0 co-funded research and innovation activity (Project ID 779613), €1.9m budget







- Couplings and hydrogen venting (CHyVe)
- New internally-funded HSE research project: 2026-2028
- Assessment of leaks from LH2 transfer connections (bayonets)
 - Aims: to improve guidance and characterise leak sizes
- Investigation of LH2 venting operations
 - Gaseous and liquid hydrogen venting experiments
 - Measure: flammable gas dispersion distances, noise, jet fire thermal radiation, and delayed explosion overpressure



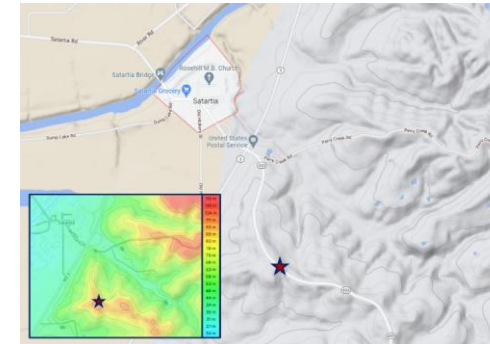
For more information: CHyVE@hse.gov.uk

Skylark: CO₂ pipeline safety – background

- Failure of Denbury 24-inch CO₂ pipeline near Satartia, Mississippi due to landslide
- Dense CO₂ cloud rolled downhill and engulfed Satartia village, a mile away
- Approximately 200 people evacuated and 45 required hospital treatment
- Communication issues: local emergency responders were not informed by pipeline operator of the rupture and release of CO₂
- Denbury's risk assessment did not identify that a release could affect the nearby village of Satartia



Figure 6: Topographical Map Showing the Delhi Pipeline (Green) and Denbury's Buffer Zone (Red) on Either Side of the Pipeline and the Proximity to Satartia (Blue Star Indicates the Rupture Site)



Terrain map taken from Google Maps and contour map taken from topographic-map.com. Approximate location of release marked by a star.

Image sources: Yazoo County Emergency Management Agency/Rory Doyle for HuffPost and PHMSA

- https://www.huffingtonpost.co.uk/entry/gassing-satartia-mississippi-co2-pipeline_n_60ddea9fe4b0ddef8b0ddc8f
- <https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/2022-05/Failure%20Investigation%20Report%20-%20Denbury%20Gulf%20Coast%20Pipeline.pdf>

Skylark: CO₂ pipeline safety

Aims (1)

- Improve our understanding of pipeline crater source behaviour
- Experimental data is currently limited to just two COSHER experiments

Moderate
wind



Bent-over plume, no CO₂ re-entrainment

Light wind



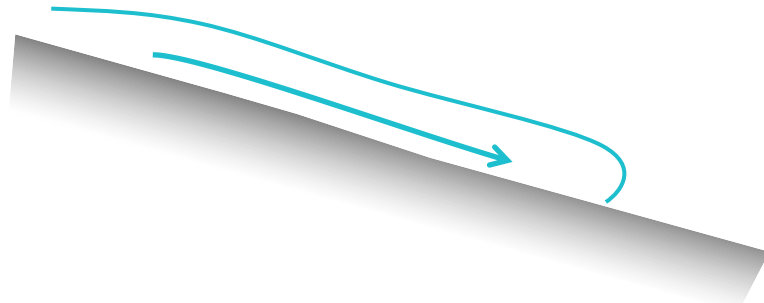
Plume fountain falls back on itself, CO₂ re-entrained, dense blanket formed

Source of images: Allason D., Armstrong K., Barnett J., Cleaver P. and Halford A. "Behaviour of releases of carbon dioxide from pipelines and vents", Paper IPC2014-33384, Proc. 10th International Pipeline Conference IPC2014, Calgary, Alberta, 29 September – 3 October 2014, © Copyright National Grid / DNV / ASME

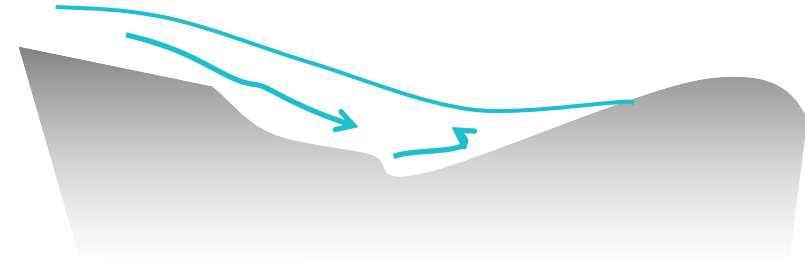
Skylark: CO₂ pipeline safety

Aims (2)

- Produce experimental data to validate dispersion models for CO₂ dispersion in complex terrain
- Encourage development and testing of dispersion models that produce results quickly, i.e., within a few seconds (or minute at most) for use in risk assessment and emergency planning/response?



Larger downslope dispersion distances?



Channelling effects in complex terrain,
vapour hold-up in valleys

Skylark: CO₂ pipeline safety

Aims (3)

- Address the needs of emergency responders
 - Learning points from Satartia incident, e.g., vehicle engines stalling in CO₂-rich atmosphere: difficulties evacuating casualties (could electric vehicles be used?)
- Similar approach could be adopted to the Jack Rabbit II chlorine dispersion experiments
 - Work led by Andy Byrnes at Utah Valley University <https://www.uvu.edu/es/jack-rabbit/>



© Images copyright DHS S&T CSAC and UVU

Skylark: CO₂ pipeline safety

- Approx £10M research project, jointly funded by DESNZ and industry
 - Timeline: 2025-2028
 - Work Package 0: Project Management – DNV
 - Work Package 1: CO₂ pipeline craters and source terms – DNV
 - Work Package 2: Wind-tunnel experiments – University of Arkansas
 - Work Package 3: Simple terrain dispersion experiments – DNV
 - Work Package 4: Complex terrain dispersion experiments – DNV
 - Work Package 5: Model validation – HSE
 - Work Package 6: Emergency response – NCEC
 - Work Package 7: Venting – DNV
- with support from the NCAS
for the DNV field trials

<https://www.dnv.com/group/joint-industry-projects/skylark-pioneering-excellence-in-co2-pipeline-safety/>

Skylark: CO₂ pipeline safety

Organisations that have expressed an interest in joining the Modellers' Working Group:

- | | | |
|-----------------------------------|---------------------------------|------------------------------------|
| 1. Abercus | 14. Gexcon Netherlands & Norway | 27. Technip UK |
| 2. Air Liquide | 15. Hanna Consultants | 28. Tetra Tech RPS |
| 3. Air Products | 16. INERIS | 29. Total Energies |
| 4. Aker Solutions | 17. Insight Numerics | 30. University of Arkansas |
| 5. Blue Engineering | 18. Kent Energies UK | 31. University of Leeds |
| 6. CERC | 19. Met Office | 32. Univ. of Liverpool John Moores |
| 7. CS ProLB | 20. MES | 33. University of Newcastle |
| 8. DNV | 21. NaTran | 34. University of Southampton |
| 9. Emergency Management Solutions | 22. Quest Consultants | 35. University of Texas A&M |
| 10. Equinor | 23. Riskaware | 36. University of TU Delft |
| 11. ESR Technology | 24. Shell | 37. Vysus Group |
| 12. Fluidyn | 25. SINTEF | 38. Wood plc |
| 13. FOI (Swedish Defence Agency) | 26. Storegga | |

If you would like to participate too, please do not hesitate to get in touch

CO₂ jet impingement experiments

- Ongoing internally-funded HSE research to investigate cooling and embrittlement of steel structures exposed to dense-phase CO₂ jets
- Instrumented steel plate
- Beam under three-point bending
- Some tests with engineered defects
- Assessment of thermal protective coatings
- Findings can be shared with third-parties

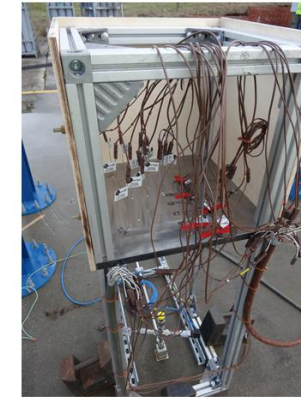
For more information:

adam.bannister@hse.gov.uk

joshua.royle@hse.gov.uk



Site overview



Steel plate
with thermocouples
(Pre-CO₂ release)



Square hollow section (SHS)
under bend load (pre-CO₂ release)



Nozzle and release system commissioning



Steel plate underside after 200s release



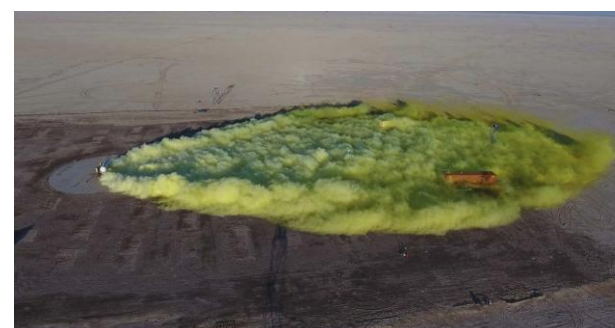
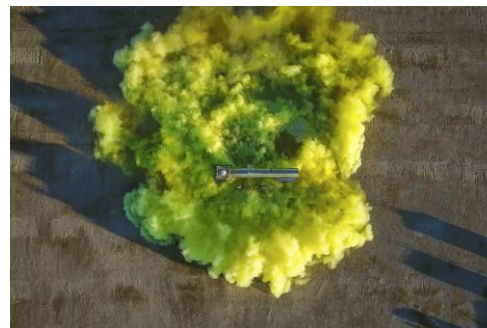
SHS underside after 200s release

Jack Rabbit III: ammonia

- Led by US Department of Homeland Security and Department of Defense/War
- Aims: – Conduct large-scale releases of ammonia, similar to Jack Rabbit II chlorine trials
 - Validate dispersion models
 - Improve preparedness of emergency responders
- HSE co-chairs the Jack Rabbit III Modelling Working Group and has coordinated an international dispersion model inter-comparison exercise (next slide)
- Recent indoor ammonia release experiments at Battelle Memorial Institute, Columbus, Ohio
- Updates often shared at GMU conference <http://camp.cos.gmu.edu/announcement.html>

Photos of Jack Rabbit II chlorine trials conducted in 2015-2016

Images © DHS S&T CSAC and Utah Valley University

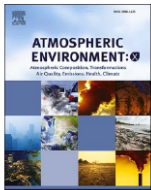




Contents lists available at ScienceDirect

Atmospheric Environment: X

journal homepage: www.journals.elsevier.com/atmospheric-environment-x



<http://dx.doi.org/10.1016/j.aeaoa.2025.100389>

<http://www.admlc.com/JR111>

Pressure-liquefied ammonia jet dispersion: Multi-model intercomparison using Desert Tortoise and FLADIS field data

^a Health and Safety Executive (HSE), Buxton, Derbyshire and Bootle, Merseyside, UK

^b RAND Corporation, Arlington, VA, USA

^c Hanna Consultants, Inc., Kennebunkport, ME, USA

^d GT Science and Software, Waverton, Cheshire, UK

^e University of Arkansas, Fayetteville, AR, USA

^f Chemical Security Analysis Center (CSAC), Science and Technology Directorate (S&T), Department of Homeland Security (DHS)

^g Defense Threat Reduction Agency (DTRA), Fort Belvoir, VA and Albuquerque, NM, USA

^h Systems Planning and Analysis, Inc. (SPA), Alexandria, VA, USA

ⁱ Swedish Defence Research Agency (FOI), Umeå, Sweden

^j EDF and École des Ponts ParisTech, Paris, France

^k European Joint Research Centre (JRC), Ispra, Italy

^l Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany

^m DNV Digital Solutions, Stockport, UK and Trondheim, Norway

ⁿ Norwegian Defence Research Establishment (FFI), Kjeller, Norway

^o Defence Science and Technology Laboratory (DSTL), Porton Down, UK

^p Gexcon, Norway and Driebergen-Rijsenburg, Bergen, Netherlands

^q Institut National de l'Environnement Industriel et des Risques (INERIS), Verneuil-en-Halatte, France

^r Syngenta, Huddersfield, Yorkshire, UK

^s Air Products, Allentown, PA, USA

^t Naval Surface Warfare Center Indian Head Division (NSWC IHD), Indian Head, MD, USA

^u Direction Générale de l'Armement (DGA), Paris, France

^v Shell, London, UK

^w Equinor, Norway

^x Emergency Management (EM) Solutions, USA

^y SINTEF Energy Research, Trondheim, Norway

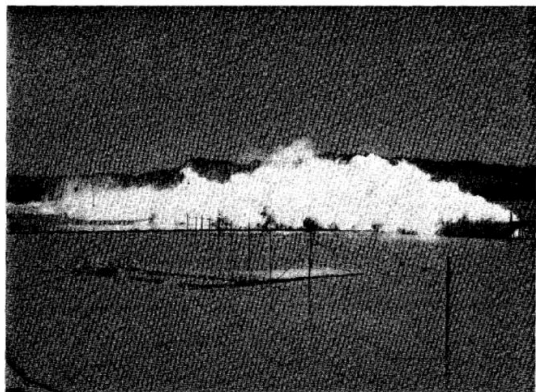
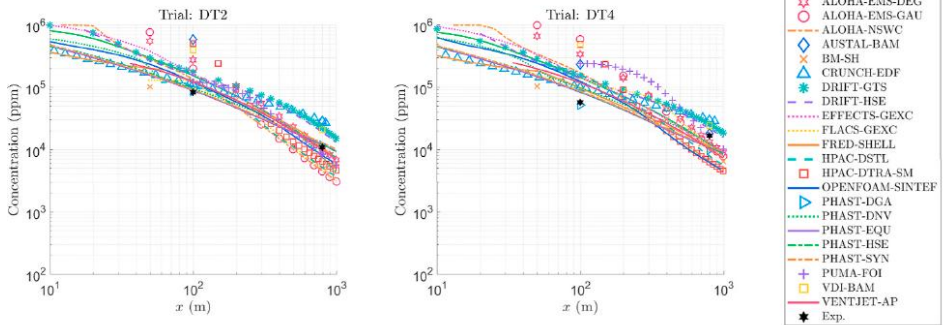


Fig. 1. Desert tortoise 2 (upside wide angle camera) Time = 230s.



Fig. 2. Photograph of one of the FLADIS ammonia trials, kindly provided to HSE by Morten Nielsen (DTU). The ammonia jet source is 1.5 m above the ground.

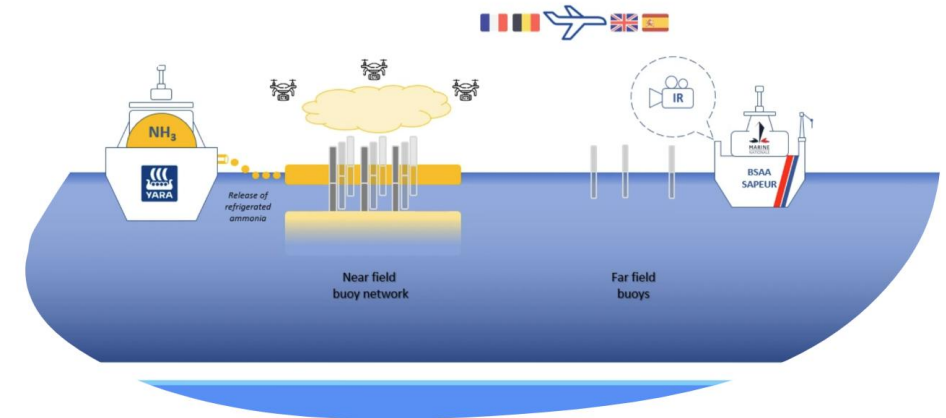


Ammonia Response in Sea Emergencies (ARISE)

- HSE is partner in the ARISE Joint Industry Project led by INERIS and CEDRE
- Aims:
 - Conduct multi-tonne spills of ammonia at sea
 - Improve understanding of dispersion in water and air
 - Provide dataset for validation of models
 - Develop methodology for risk assessment for marine applications
- Experiments planned for 2026
- Contact: Olivier.Salvi@ineris-developpement.com



www.arise-partnership.org

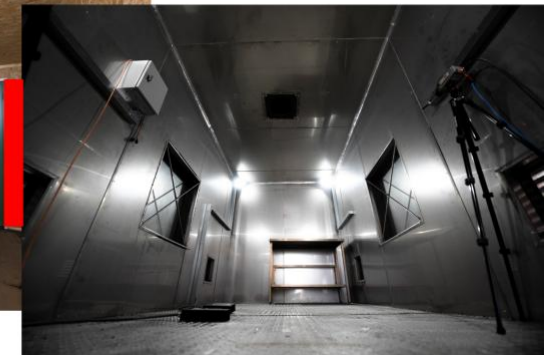


Yara Clean Ammonia



HSE battery abuse testing facilities

- Significant investment by HSE over last 10 years
- Three abuse test chambers (1 module scale, 1 with potential calorimetric addition)
- Use of outdoor test pads/bunkers
- Range of other facilities and equipment



Some recent battery publications



Energy Advances

ROYAL SOCIETY OF CHEMISTRY

PAPER

Check for updates

Experimental determination of metals generated during the thermal failure of lithium ion batteries†

Cite this: *Energy Adv.*, 2023, 2, 170

Jonathan E. H. Buston*, Jason Gill, Rebecca Lisseman, Jackie Morton, Darren Musgrove and Rhiannon C. E. Williams

<https://doi.org/10.1039/D2YA00279E>

Journal of Power Sources 539 (2022) 231585



Contents lists available at ScienceDirect

Journal of Power Sources

journal homepage: www.elsevier.com/locate/jpowsour

Comprehensive gas analysis of a 21700 Li(Ni_{0.8}Co_{0.1}Mn_{0.1}O₂) cell using mass spectrometry

Katie C. Abbott, Jonathan E.H. Buston, Jason Gill, Steven L. Goddard, Daniel Howard, Gemma Howard, Elliott Read, Rhiannon C.E. Williams

HSE Science and Research Centre, Harpur Hill, Buxton, Derbyshire, SK17 9JN, United Kingdom

<https://doi.org/10.1016/j.jpowsour.2022.231585>

Journal of Energy Storage 65 (2023) 107293



Contents lists available at ScienceDirect

Journal of Energy Storage

journal homepage: www.elsevier.com/locate/est

Research papers

Experimental study of three commercially available 18650 lithium ion batteries using multiple abuse methods

Katie C. Abbott, Jonathan E.H. Buston*, Jason Gill, Steven L. Goddard, Daniel Howard, Gemma E. Howard, Elliott Read, Rhiannon C.E. Williams

HSE Science and Research Centre, Harpur Hill, Buxton, Derbyshire SK17 9JN, United Kingdom

<https://doi.org/10.1016/j.est.2023.107293>



batteries

MDPI

Article

Comprehensive Study of the Gas Volume and Composition Generated by 5 Ah Nickel Manganese Cobalt Oxide (NMC) Li-Ion Pouch Cells Through Different Failure Mechanisms at Varying States of Charge

Gemma E. Howard*, Katie C. Abbott, Jonathan E. H. Buston, Jason Gill, Steven L. Goddard and Daniel Howard

<https://doi.org/10.3390/batteries11050197>

RSC Advances

ROYAL SOCIETY OF CHEMISTRY

PAPER

View Article Online
View Journal | View Issue

Check for updates

Failure gas analysis of lithium–nickel–cobalt–aluminium oxide cells from different manufacturers

Cite this: *RSC Adv.*, 2025, 15, 5064

Philip A. P. Reeve, Jonathan E. H. Buston*, Jason Gill, Steven L. Goddard, Gemma E. Howard and Jack W. Mellor

<https://doi.org/10.1039/D4RA07884E>

Other papers currently submitted relating to

- Gas produced by LFP cells
- Gas produced by a range of other cells
- Deflagrations caused by LFP cells
- Battery recycling



31st International Conference on Modelling, Monitoring and Management of Air Pollution

Thank you

simon.gant@hse.gov.uk

This presentation and the work it describes were funded by the Health and Safety Executive (HSE). Its contents, including any opinions and/or conclusions expressed, are those of the authors alone and do not necessarily reflect HSE policy.

Why the name Skylark?

Historical dispersion trials

- **Avocet:** LNG
- **Burro:** LNG
- **Coyote:** LNG
- **Desert Tortoise:** ammonia
- **Eagle:** nitrogen tetroxide
- **Falcon:** LNG
- **Goldfish:** hydrogen fluoride
- **Kit fox:** carbon dioxide
- **Jack Rabbit:** chlorine and ammonia
- **Red Squirrel:** ammonia
- **Skylark:** carbon dioxide



<https://www.birdguides.com/gallery/birds/alauda-arvensis/1003602/>